Quantifying the Q-Factor and Minimizing BER in 32-Channel DWDM System Design Using EDFA and RAMAN Amplifiers

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ABSTRACT

In this work we have designed, modeled and simulated a 32-channel DWDM (Dense Wavelength Division Multiplexing) system using OptiSystem photonic simulator. The system is tested for external transmitter with NRZ (Non-Return Zero) encoder using Mech-Zehnder modulator, which accepts input from CW (Continuous Wave) laser array and low pass Bessel filter that supports PIN photodiode at receiver end. System performance for optical channels has been compared by varying channel length of EDFA (Erbium Doped Fiber Amplifier) and Raman amplifiers to identify its impact in the sense of eye diagram, QF (Quality Factor) and minimum BER (Bit Error Rate). Experimental setup was done by varying channel lengths of 60, 100, 120, 150 and 170Kms. It was found that EDFA has better performance in the sub-low ranges of 60Kms, whereas Raman offers better performance at wider channel lengths i.e. more than 100Kms. The proposed work can be extend for the avoidance of amplifier utilization at wider ranged.

Key Words: **Dense Wavelength Division Multiplexing System, Erbium Doped Fiber Amplifier and Raman Amplifiers, Eye Diagram, Q-Factor, Minimum Bit Error Rate.**

1. INTRODUCTION

The technological escalation and oversized internet usage is quite visible from continuously increasing bandwidth requirements ensuing for high cost infrastructure [1]. Therefore, a cost effective, secure and efficient way of transmission is always a concern. Various optical techniques have been used in telecommunication system, where carrier wave functions in an optical domain [2].

DWDM is a transmission scheme system that relies on guided medium, is capable of multiplexing diverse wavelengths on to an identical fiber medium. The wave modulation scheme can have the signal transmission rate in GHz (Gigahertz) ranges while at the same time high frequency carrier in the vicinity of 186-196 THz (Terahertz) can also be generated [3]. The bit rate can be improved even more if needed through multiple carrier waves, exclusive of any propagating interface with each other even though they can still share the same fiber medium. Process relies on WDM where every frequency works on a different wavelength. Every fiber carries a number of optical channels with variable light wavelengths in

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analogous patterns. DWDM utilizes photon wavelengths to transmit data bit by bit in parallel form. DWDM is specifically used for adjacent spaced frequencies not more than 100GHz or 0.8nm typically at wavelength window of 1550nm. With WDM technique it is quite possible that shared sources can emit at dissimilar wavelengths like λ_1, λ_2, λ_3, λ_4....λ_n contained by the same optical fiber [4]. Subsequent to the transmission, λ_1, λ_2, λ_3 λ_4....λ_n can be alienated using specific sort of detectors at the receiving node [5]. Signals acquired from various sources are injected through multiplexing components at the transmitting node, then demultiplexer components are used to separate the wavelengths.

2. 32 CHANNEL DWDM SYSTEM DESIGNING ASPECTS

The typical 32 channel DWDM system design can be alienated into three sections, DWDM Transmission, DWDM Channel and DWDM Receiving.

2.1 DWDM Transmission

With DWDM transmission an externally modulated transmitter and lasers are preferred due to stability factor. In external modulation, output power of the laser is modulated in to an external cavity, which avoids the affects of nonlinearity that can distress signal bandwidth. In this research work laser input from the CW laser is obtained through NRZ modulation along with MZI (Mach Zehnder Interferometer) modulator. MZI modulator can offer twice the bit rate of their allocated bandwidth; this gives windows of reducing the space between adjacent channels in a WDM [6].

2.2 DWDM Channel

A practical DWDM system contains of different types of channels, but in this work we have only analyzed EDFA pumped fiber channel and Raman pumped fiber channel.

2.2.1 EDFA Pumped Fiber Channel

In EDFA pumped fiber channel, signals are amplified while optical pumps are superimposed. The pump agitates the doping ions like erbium to an upper energy scale from where amplification is performed through stimulated emissions. Erbium fiber amplifiers are especially suitable for the 1550nm transmission window [5].

In this work we have also analyzed the combined impacts of SMF (Single Mode Fiber) and DCF (Dispersion Compensating Fiber) to a medium having EDFA as an amplifier. In order to compensate the linear losses particularly after 50km EDFA is added during channel designing [7]. In 1550nm optical fiber window, linear dispersion can restrict the high speed signal [8].

The dispersion of SMF at 1550nm window is around 16.75ps/nm/km; so DCF technique should be preferred to balance the dispersion. Considering that chromatic dispersion of DCF in negative range (-90ps/nm/km), total transmission line dispersal value will be close to zero at the estimated length of about 10km (1/5th) of the SMF [2]. The larger attenuation of DCF can be compensated by minimizing the linear loss at the channel's end after DCF using EDFA.

2.2.2 Raman Pumped Fiber Channel

Raman dispersion converts a specific part of an incident frequency in to sub-recognized frequencies, in a way that energy can be transferred from pump laser to a weak signal, which turn-up into simultaneous amplification of several multiplexed wavelengths, by considering crosstalk between channels [9]. A Raman pumped amplifier based channel design is based on Raman amplifier average power model and specific channel length. The adopted Raman amplifier model for 32-channel DWDM system is shown in Fig.1. Raman amplification operating ranges vary around 1330-1550nm window with pumps at 1240 and 1420nm respectively, with propagating bandwidth of 65 and 100nm [10-11]. Unlike EDFA, minimized nonlinear crosstalk may be achieved by Raman amplifiers while used in distributed amplifiers at the cost of extra pump power [12].

2.3 DWDM Receiving

Communication channel length depends upon factors like; detectors, filters, demodulators and modulation techniques. However, receiver noise can be controlled by low pass Bessel filter that is directly proportional to bandwidth. Decision making circuit recognizes the 1 and 0 logic of the signal while a real-time clock recovery circuit compares the linear channel output and threshold value. In the requirement of cascading the DWDM light receiving parameters, after PIN photodiode, low pass Bessel filter having 4xbit rate of bandwidth and cut off frequency of 0.75xbit rate can be connected as parameters with BER analyzer.

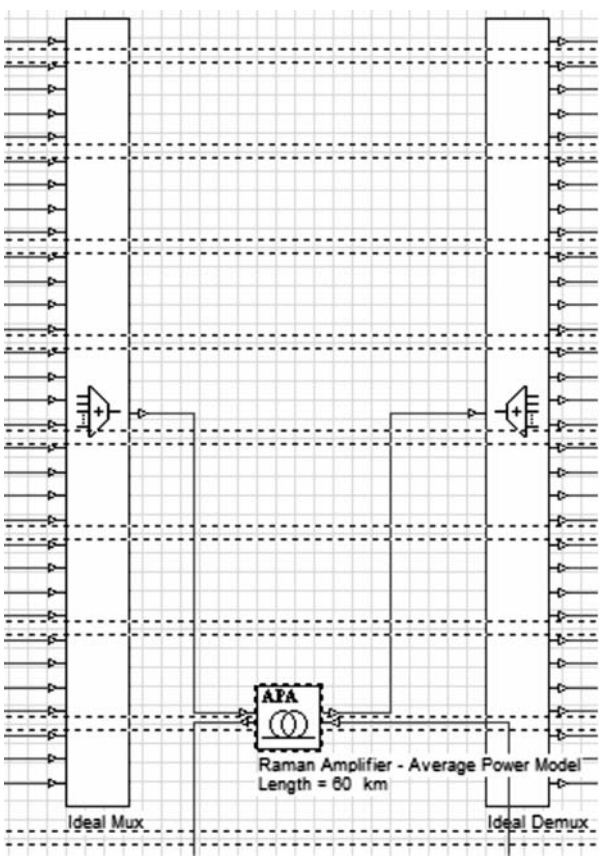

FIG. 1. RAMAN AMPLIFIER MODEL FOR 32-CHANNEL DWDM SYSTEM

3. 32 CHANNEL DWDM SYSTEM DESIGN MODEL USING EDFA AND RAMAN AMPLIFIERS

We have designed, modeled and simulated a 32-channel DWDM system as shown in Fig. 2. The designed system was compared for the characteristics of EDFA and Raman Amplifier on the parameters like eye diagram, QF and Minimum BER at different channel lengths. The designed model at the DWDM receiving side accepts one input and generates thirty two outputs. With every generated output a PIN photo detector is attached to detect signals and convert them into electrical signal. The converted electrical signal is passed through low pass Bessel filter to reject all the unwanted higher frequencies. The accepted signals are investigated through BER analyzer, which generates results in the form of Eye diagram, QF and minimum BER. The design model is also tested for the EDFA+SMF+DCF channel combination as proposed by [12].

4. SIMULATION RESULTS AND DISCUSSION

In this section EDFA and Raman amplifier's performance has been investigated and compared on Eye diagram, minimum BER and QF parameters keeping the length constant to 60km. By varying the channel distance lengths to 96 and 100km, process has been repeated to justify the performance characteristics of EDFA and Raman Amplifiers.

4.1 EDFA and Raman Amplifiers Performance Investigation at 60km

In the following section, we have discussed the EDFFA and Raman amplifier performance investigation at 60Km. The combined impacts of SMF and DCF have also been investigated to a medium having EDFA as an amplifier.

4.1.1 EDFA and Raman Amplifiers Eye Diagram Performance Investigation at 60km

In Figs. 3-4, EDFA and Raman channel eye diagram is shown. In Fig. 3, it can be seen that with EDFA the presence of vertical eye aperture represents the discrepancy in signal level that point out the divergence in 1 and 0s logic bits. It is quite observable that eye opening is quite narrow but favorably jitters are not so much noticeable. Fig. 4 clarifies the perfect shape of eye diagram indicating that again no jitters are observable at horizontal and vertical opening, so it will be quite straightforward to differentiate in the course of 1 and 0s logics.

4.1.2 EDFA and Raman Amplifiers Minimum BER Performance at 60km

In Figs. 5-6, EDFA and Raman Amplifiers minimum BER performance is shown.

In Fig. 5 EDFA minimum observed BER value is 1.9476e-014, whereas Fig. 6 plot results illustrates that when Raman amplifier is used, all bits are received and acknowledged due to its capability of zero BER, which reflects the ideal results.

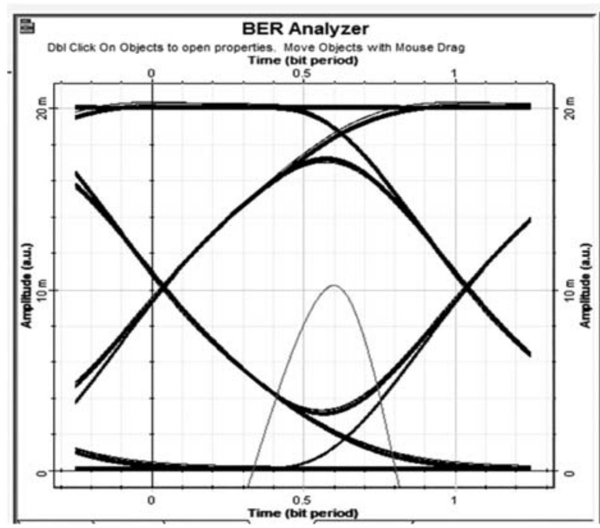

FIG. 3. EDFA EYE DIAGRAM IN CONJUNCTION WITH SMF AND DCF AT 60KM

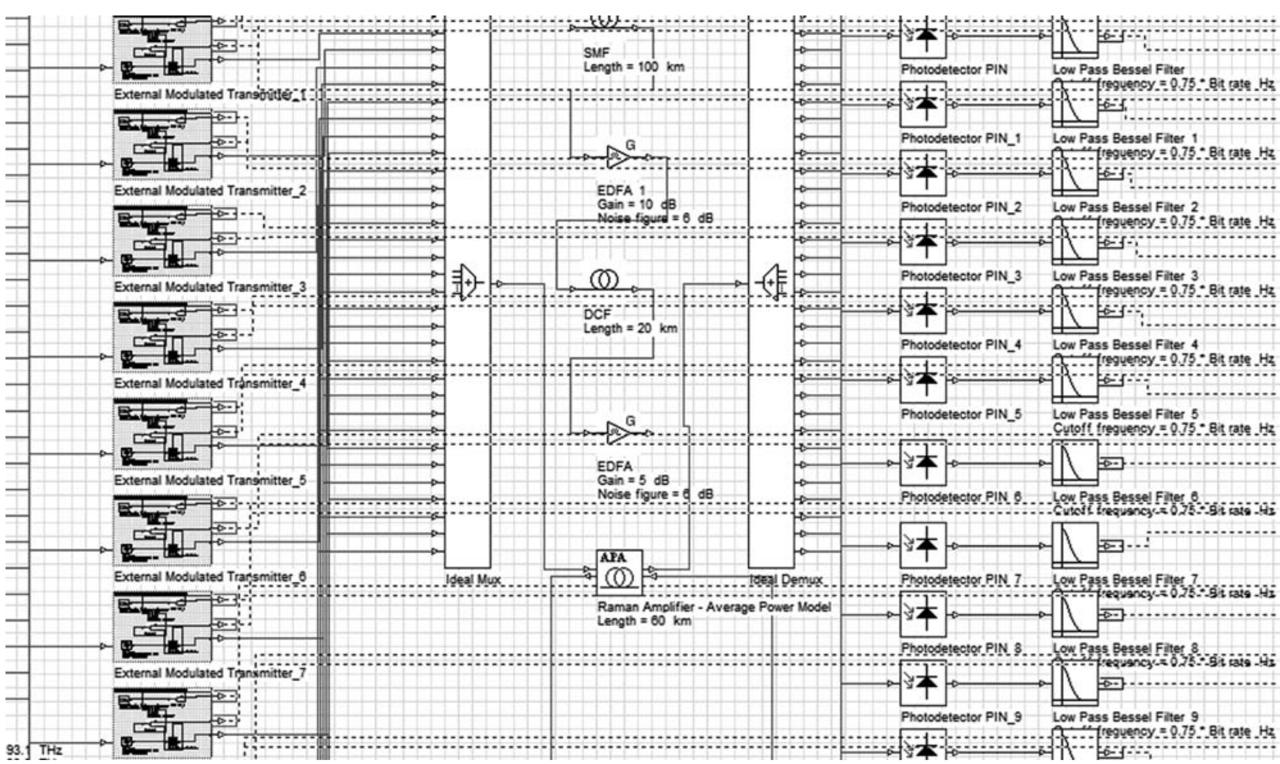

FIG. 2. 32-CHANNEL DWDM SYSTEM DESIGN MODEL USING EDFA AND RAMAN AMPLIFIERS

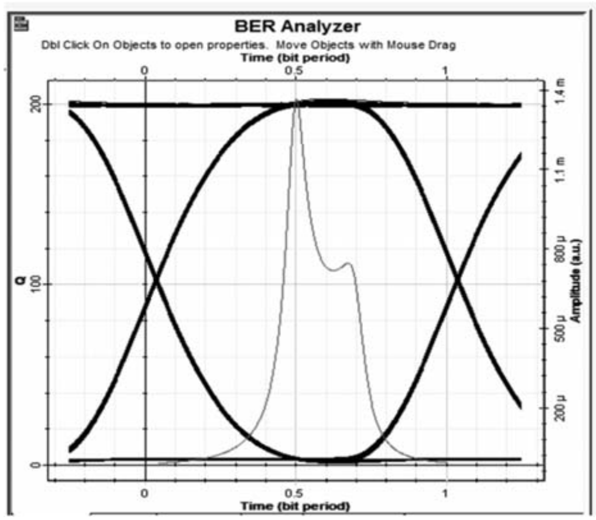

FIG. 4. RAMAN AMPLIFIER'S EYE DIAGRAM AT 60KM

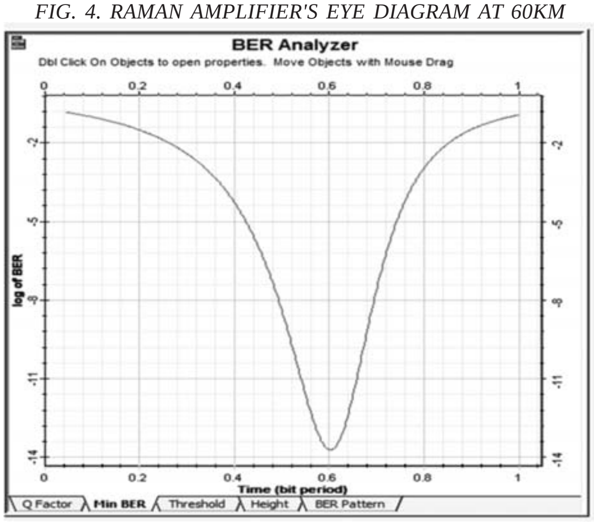

FIG. 5. EDFA MINIMUM BER WITH SMF AND DCF AT 60KM

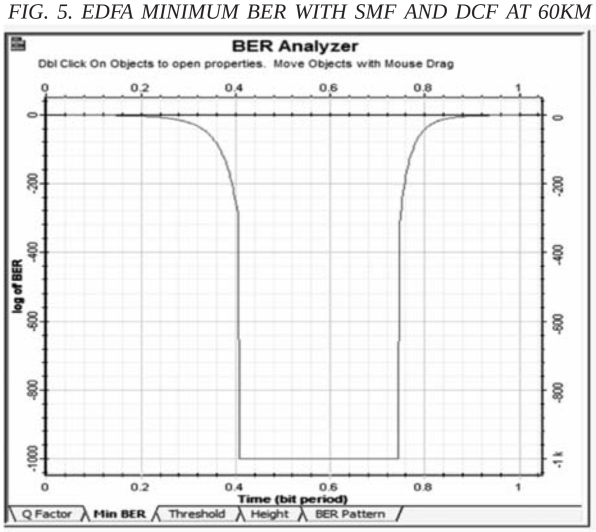

FIG. 6. RAMAN AMPLIFIER'S MINIMUM BER AT 60KM

4.1.3 EDFA and Raman Amplifiers QF Comparison at 60km

In Figs. 7-8, EDFA and Raman Amplifiers QF performance is shown. Fig. 7 shows that QF of 7.56443 is recorded by using EDFA which is within satisfactory range, as QF of any value greater than 7.00 is always acceptable. Fig. 8 illustrates that QF of 202.661 is obtained by using Raman amplifier.

From the above results, we can conclude that, Raman amplifiers have better results than EDFA. Even though

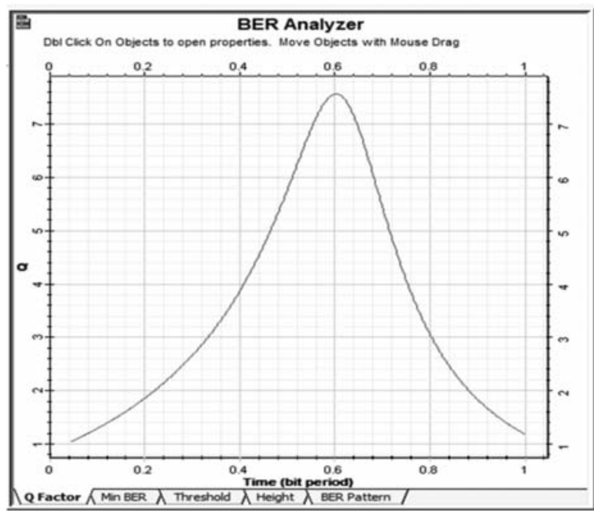

FIG. 7. EDFA Q-FACTOR ALONG WITH SMF AND DCF AT 60KM

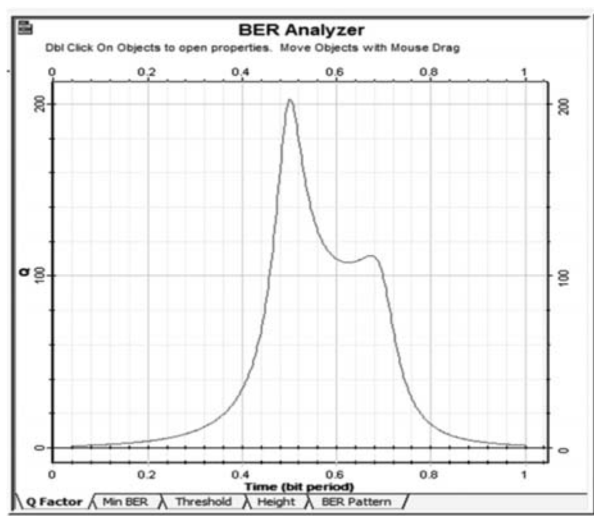

FIG. 8. Q-FACTOR OF RAMAN AMPLIFIER AT 60KM

EDFA simulations were based on unidirectional traffic compared to Raman amplifiers which were analyzed for unidirectional as well as bidirectional traffic within predetermined distances. Raman amplifiers results encourage us to investigate the behavior at longer distance. Eventually it was tested at 100 and 120km distances.

4.2 EDFA and Raman Amplifiers Performance Investigation at 100km Channel Distance with Integrated Parameters

In the following section, we have discussed the EDFA and Raman amplifier performance investigated at 100km channel distance. Here we have investigated all the parameter results of Eye diagram, minimum BER and QF parameters in a single plot.

4.2.1 Eye Diagram, Minimum BER and QF Comparison between EDFA and Raman Amplifier at 100 km

In Figs. 9-10, EDFA and Raman channel eye diagram, minimum BER and QF results are shown. Unlike 60Km performance, EDFA plot (Fig. 9) shows that eye opening varies marginally and QF is trimmed down to 2.43803. Similarly, minimum BER is increased up to 0.0073794. However, at the same channel length, Raman pumped fiber channel has wider open Eye with QF of 82.8937 compared to EDFA. Like 60Km, minimum BER is managed to zero and results are still under control. Hence, Raman amplifier can handle bidirectional traffic at longer distances and wider length.

4.2.2 Eye Diagram, minimum BER and QF Comparison between EDFA and Raman Amplifier at 120 km

In Figs. 11-12, EDFA and Raman channel eye diagram, minimum BER and QF results are shown at 120 Km.

In Fig.11, it can be seen that EDFA signal strength has been lost and only noise is available. However, Raman Amplifier offers satisfactory performance at 120Km (Fig. 12). It is evident that the Eye opening is at good level and QF have been reduced that is within recommended range i.e. QF>7. Similarly, minimum BER is on the rise at 4.32179e-217 that is smaller than 10e-9.

Overall results indicate that at wider distance Raman Amplifiers have better results as compared to EDFA amplifiers. At 120km distance Raman Amplifier's Eye

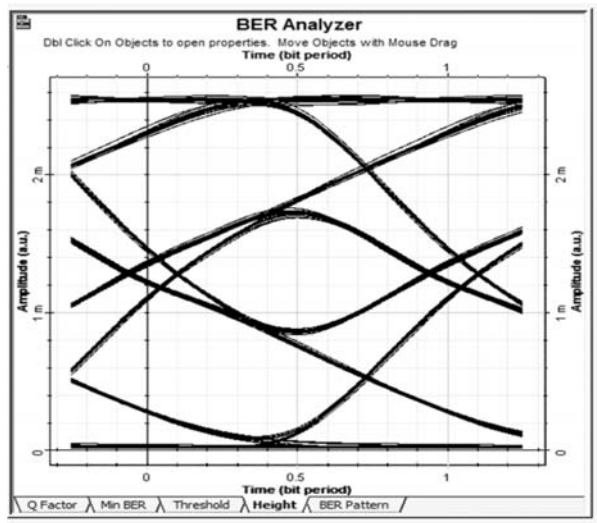

FIG. 9. EDFA EYE DIAGRAM BY CONSIDERING SMF AND DCF AT 100KM

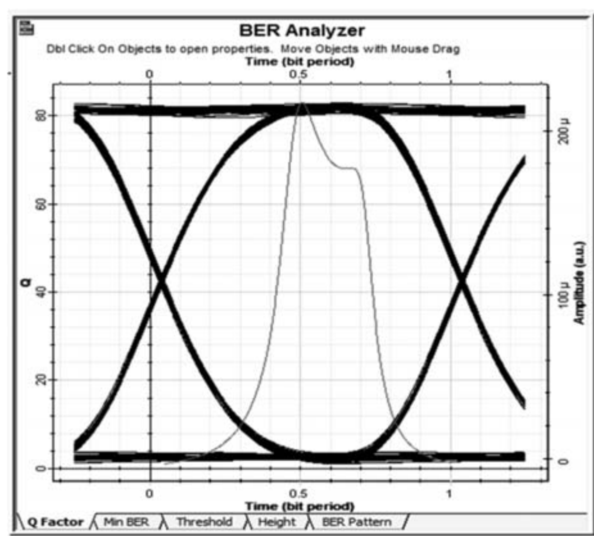

FIG. 10. RAMAN AMPLIFIER'S PERFORMANCE AT 100KM

opening is at good level, QF is still within recommendable range (QF>7), while minimum BER is marginally on the rise. These results further motivated us to investigate the performances of Raman Amplifier at even more distance. For this purpose 150 and 170km distance were selected.

4.3 Raman Amplifier Performance Investigation at 150 and 170km Distance

In Figs. 13-14, Raman channel eye diagram, minimum BER and QF results are shown at the distance of 150 and 170km.

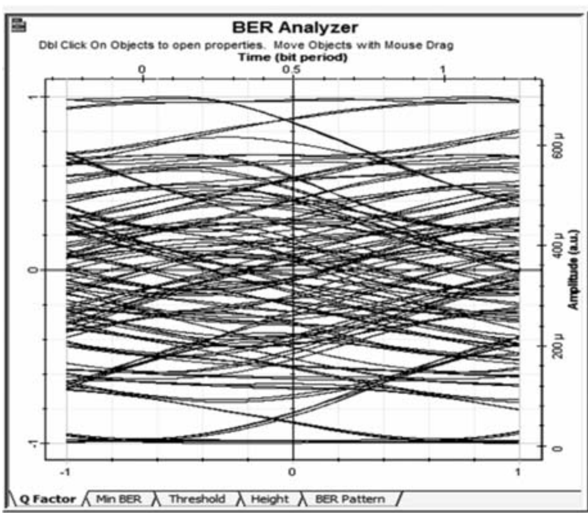

FIG. 11. EDFA EYE DIAGRAM WITH SMF AND DCF CONSIDERATION AT 120KM

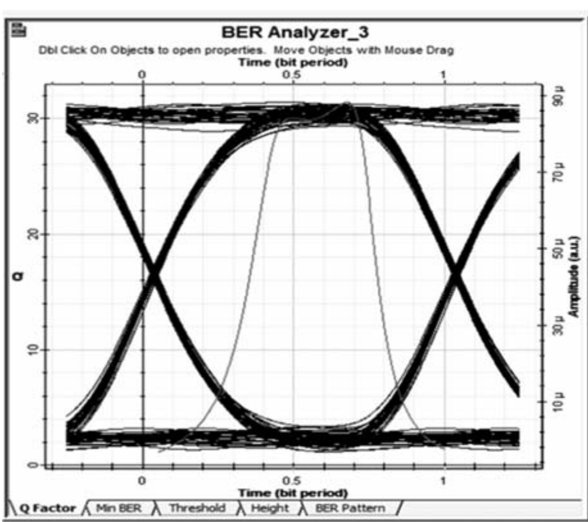

FIG. 12. RAMAN AMPLIFIER PERFORMANCE AT 120KM

The results shown in Fig. 13 are adequate, since jitter and noise has greater values than before while eye opening is reduced significantly; QF is also very low while BER has increased marginally. Fig. 14 gives a picture of almost noise like signal, with QF and minimum BER values are also not in acceptable ranges.

These results show that Raman Amplifiers are reasonable up to 150km, but when we increase channel length up to 170km, than result starts to decline below to recommended values.

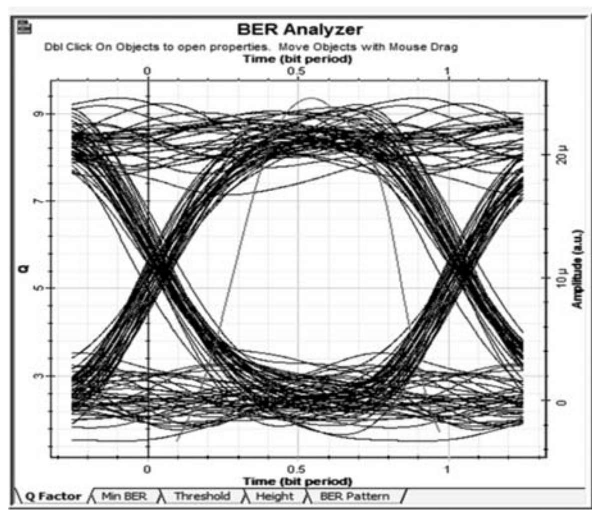

FIG. 13. RAMAN AMPLIFIER PERFORMANCE AT 150KM

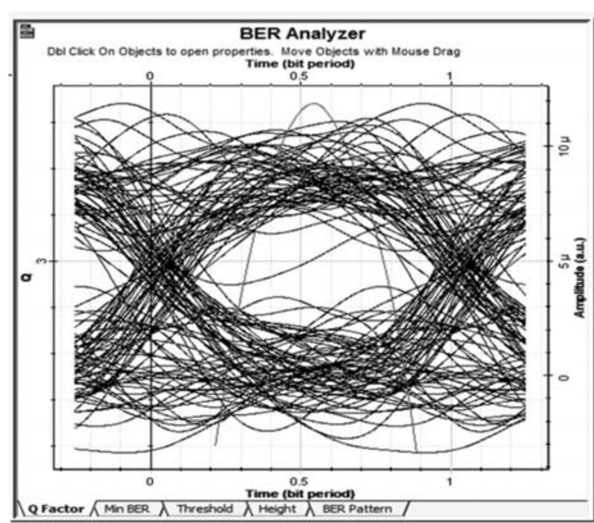

FIG. 14. RAMAN AMPLIFIER PERFORMANCE AT 170KM

5. CONCLUSION

In this work, we have designed, modeled and investigated 32-channel DWDM system. All the experimental results have been compared and analyzed with three parameters; Eye Diagram, QF and Minimum BER. We have also tested the EDFA+SMF+DCF channel combination, but this combination has only acceptable results within 60km range. On the other hand EDFA pumped fiber channel performance in comparison to Raman pumped fiber channel, declines after 60km distance, nearly un-acceptable at 100km and noise was observed at 120km. While Raman pumped fiber channel looks ideal up to 100km, and acceptable up to 120km and satisfactory up to 150km, but when we increase channel length to 170kms, than observed results were below the recommended values.

Finally we can conclude that for 32-channel DWDM system, Raman pumped fiber channel offers consistently better performance than EDFA pumped fiber channel with better eye opening, greater QF and minimum BER.

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